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Probiotic Therapy in Hypertension: A Review of Evidence from Animal and Human Models

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A B S T R A C T

Objective: Hypertension is one of the most prevalent cardiovascular disorders, substantially increasing the risk of heart disease, stroke, and kidney failure. Emerging evidence indicates that disruptions in gut microbiota may play a critical role in blood pressure regulation, positioning probiotics as a promising adjunctive approach for hypertension management. This review aims to synthesize findings from both animal and human studies regarding the role of probiotics in modulating blood pressure and to elucidate the underlying mechanisms, thereby evaluating the potential of probiotic therapy as a complementary strategy in hypertension management.

Methods: A comprehensive literature search was performed for studies published between 2010 and 2025 in major databases, including PubMed, Scopus, Web of Science, Google Scholar, and the Islamic World Science Citation Center (ISC). The search strategy combined keywords related to “probiotics,” “blood pressure,” and “hypertension.” Following duplicate removal, titles and abstracts were independently screened, and studies meeting predefined eligibility criteria were included. The final analysis focused on the effects of probiotics on blood pressure regulation.

Results: Evidence from meta-analyses, clinical trials, and animal studies indicates that the consumption of probiotics and fermented products can induce modest yet statistically significant reductions in both systolic and diastolic blood pressure, particularly in individuals with hypertension, type 2 diabetes, or elevated baseline blood pressure. These effects are primarily mediated through improvements in gut microbiota composition, enhanced production of short-chain fatty acids (SCFAs), reduced inflammation and oxidative stress, and improved endothelial function via nitric oxide pathways. Higher doses, interventions lasting at least eight weeks, multi-strain formulations, and fermented dairy products appear to confer greater efficacy, although the observed effects are often short-term and of moderate clinical magnitude.

Conclusion: Current evidence from animal and human studies supports the potential of probiotic therapy as a safe and complementary strategy for blood pressure management, especially in individuals with hypertension, prediabetes, or type 2 diabetes. The blood pressure-lowering effects of probiotics are largely mediated by modulation of gut microbiota, increased SCFA production, attenuation of systemic inflammation and oxidative stress, and enhancement of endothelial function. Nevertheless, heterogeneity in probiotic strains, dosages, intervention durations, and population characteristics limits the generalizability of these findings.

Keywords: Probiotics, Blood pressure, Gut microbiota, Systemic inflammation, Cardiovascular health

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Introduction

Hypertension is one of the most prevalent cardiovascular disorders worldwide, significantly increasing the risk of heart disease, stroke, heart failure, and kidney dysfunction [1]. It is characterized by chronically elevated blood pressure in the arteries, which gradually damages blood vessels and target organs [2]. Effective blood pressure control is essential due to the substantial economic and social burden of the disease, its negative impact on quality of life, and its association with increased mortality [3]. Globally, hypertension is a leading contributor to non-communicable diseases and premature death, making its management a major public health priority [4].

The etiology of hypertension is multifactorial, including genetic predisposition, lifestyle factors, high-salt and high-fat diets, obesity, physical inactivity, chronic stress, and metabolic disturbances [5]. Emerging evidence also highlights the role of gut microbiota dysbiosis in the development and progression of hypertension, potentially via its influence on metabolism, autonomic nervous system regulation, and the renin–angiotensin system [6].

Pathophysiologically, hypertension involves endothelial dysfunction, chronic systemic inflammation, increased peripheral vascular resistance, and hormonal imbalances that regulate blood pressure [7]. These mechanisms collectively contribute to elevated systolic and diastolic pressures and progressive damage to the heart, kidneys, and brain (8). Notably, alterations in gut microbiota have been shown to affect inflammatory pathways and blood pressure regulation, suggesting that probiotics may help restore microbial balance and support blood pressure control [7,8].

Hypertension can lead to severe complications, including stroke, myocardial infarction, kidney failure, visual impairment, and widespread vascular damage [9]. Patients may also experience fatigue, headaches, and a reduced quality of life, and uncontrolled hypertension poses a life-threatening risk [9]. Diagnosis is typically based on repeated blood pressure measurements, evaluation of cardiovascular risk factors, and assessment of target organ function [10]. Early detection is crucial for preventing complications and selecting appropriate therapeutic strategies [10].

Management of hypertension includes both pharmacological and non-pharmacological approaches. Non-pharmacological interventions comprise dietary modifications, weight reduction, regular physical activity, and stress management [11], while pharmacological therapy involves ACE inhibitors, angiotensin receptor blockers, diuretics, and beta-blockers [12]. Although effective, these medications may cause adverse effects, drug interactions, and require long-term monitoring. Consequently, safe complementary therapies, such as probiotics, have received increasing attention [13].

Complementary strategies in blood pressure management have gained recognition in recent years [14]. These approaches aim to reduce systemic inflammation, enhance metabolic function, and support gut microbiota health, positioning them as potentially effective adjuncts to conventional treatment.

Probiotics are live microorganisms which, when administered in adequate amounts, confer health benefits by maintaining or restoring microbial balance in the host [15]. They have been implicated in the prevention and management of diverse conditions including cardiovascular, gastrointestinal, metabolic, inflammatory, and immune-related disorders through mechanisms such as strengthening biological barriers and modulating immune responses [16].

By modulating gut microbiota composition and influencing short-chain fatty acid (SCFA) metabolism, probiotics may play a significant role in blood pressure regulation [17]. Evidence suggests that specific probiotic strains can reduce inflammation, improve endothelial function, and inhibit pathways associated with elevated blood pressure [18].

The present review aims to evaluate current evidence on the application of probiotics in the prevention and management of hypertension, focusing on their effects on gut microbial balance, systemic inflammation, endothelial function, and cardiovascular risk factors. This analysis seeks to provide a deeper understanding of the potential of probiotics as a safe and effective complementary approach in blood pressure management.

Methods

This study was conducted as a narrative–analytical review. A systematic literature search was performed for articles published between 2010 and 2025 in the databases PubMed, Scopus, Web of Science, Google Scholar, and the Islamic World Science Citation Center (ISC). The search strategy employed a combination of keywords and phrases, including “probiotics,” “blood pressure,” “hypertension,” “gut microbiota,” and “cardiovascular health,” using Boolean operators (AND/OR) to refine the results.

Following the initial retrieval, duplicate records were removed, and a two-step screening process was undertaken. First, titles and abstracts were independently evaluated for relevance. Subsequently, the full texts of eligible articles were assessed in detail.

Inclusion criteria were as follows:

Human studies, including randomized controlled trials, interventional studies, systematic reviews, and meta-analyses, as well as relevant animal studies investigating blood pressure;

Studies examining the effects of probiotic or fermented product consumption on systolic and/or diastolic blood pressure;

Articles published in English or Persian;

Availability of full-text articles.

Exclusion criteria included:

Studies lacking quantitative or qualitative blood pressure data;

Non-systematic reviews, case reports, letters to the editor, and conference abstracts;

Studies in which the probiotic intervention was unspecified or not reproducible;

Articles with low methodological quality or insufficient information.

Selected studies were qualitatively analyzed and synthesized, with particular emphasis on the clinical effects of probiotics on blood pressure and the underlying mechanisms, including modulation of gut microbiota, systemic inflammation, endothelial function, and nitric oxide pathways.

Results

Evidence from human studies, particularly meta-analyses and systematic reviews, indicates that consumption of probiotics and fermented products is associated with modest but statistically significant reductions in both systolic and diastolic blood pressure. These effects appear to be more pronounced in individuals with hypertension, type 2 diabetes, or elevated baseline blood pressure.

Regarding intervention characteristics, longer durations of at least eight weeks, higher doses, multi-strain formulations, and fermented dairy products generally demonstrate greater efficacy. However, consistent differences between single-strain and multi-strain probiotics have not been observed across all studies, and treatment responses often vary according to individual and demographic factors.

Clinical trials report heterogeneous outcomes. Some studies demonstrated significant reductions in blood pressure or improvements in metabolic indices, whereas others found no statistically significant changes. This variability likely reflects differences in study design, probiotic strains, dosages, duration of intervention, and population characteristics.

In contrast, animal studies have consistently supported the antihypertensive effects of probiotics. Proposed mechanisms include modulation of gut microbiota composition, increased production of short-chain fatty acids (SCFAs), enhanced endothelial function, upregulation of nitric oxide pathways, and reductions in systemic inflammation and oxidative stress.

Overall, the available evidence suggests that probiotic therapy may serve as a beneficial adjunct in blood pressure management. Nevertheless, the observed effects are generally moderate and short-term, emphasizing the need for further well-designed, long-term clinical studies. Detailed findings are summarized in Table 1.

Table 1: Summary of evidence from human and animal studies on the effects of probiotics and fermented products on blood pressur

Study Type / Population	Sample Size	Probiotic / Fermented Product	Duration	Dose / Strains	Main Findings	Reference
Meta-analysis / Hypertensive patients	846	Probiotics	Variable	Variable	Significant reductions in SBP, DBP, BMI, and blood glucose; stronger effect in diabetics; no difference between single- and multi-strain	[19]
Systematic review & Meta-analysis / Adults	9 RCTs	Probiotics	≥8 weeks	$\geq 10^{11}$ CFU, multi-strain	Moderate reductions in SBP (3.56 mmHg) and DBP (2.38 mmHg); more pronounced in baseline BP ≥130/85 mmHg	[20]
Meta-analysis / Adults	702	Fermented probiotic milk	Variable	Variable	Moderate reductions in SBP (3.10 mmHg) and DBP (1.09 mmHg); stronger effects in hypertensive individuals and Japanese studies	[21]
Meta-analysis / Adults	653	*Lactobacillus plantarum*	Variable	Single-strain	Modest reductions in SBP (1.58 mmHg) and DBP (0.92 mmHg); clinically small but safe effect	[22]
Umbrella meta-analysis / Adults	2,703 (1,009 T2DM)	Probiotics, dairy, fermented products	≥8 weeks	$\geq 10^{11}$ CFU, multi-strain	SBP reduction 3.10–5.04 mmHg, DBP 0.39–3.84 mmHg; more pronounced in BP ≥130/85 mmHg, dairy products, Asia, multi-strain	[23]
Animal / SHR rats	-	*L. fermentum* LC40, *B. breve* BFM	Variable	Variable	Prevented BP elevation, mitigated dysbiosis and endothelial dysfunction, increased SCFAs, improved Th17/Treg balance, reduced ROS and endotoxemia	[24]
Animal / Mice, High-fructose diet	-	*B. lactis* M8, *L. rhamnosus* M9	Variable	Variable	Reduced SBP and DBP, altered gut microbiome, modulated glutamine/glutamate metabolism and smooth muscle contraction pathways	[25]
Umbrella meta-analysis / Adults	15,494	Probiotic supplements	≤10 weeks	$\geq 10^{10}$ CFU	SBP −1.96 mmHg, DBP −1.28 mmHg; greater SBP reduction in >50 years, DBP at higher doses	[26]

Animal / SHR rats	-	Probiotic yogurt	Variable	Variable	Reduced BP and improved cardiac function, increased microbial diversity and SCFAs; effects dependent on microbiota restoration	[27]
Systematic review & Meta-analysis	2,037	Probiotics, fermented milk, other forms	8–10 weeks	Variable	SBP −3.05 mmHg, DBP −1.51 mmHg; stronger effects in hypertensive and T2DM individuals; short-term effect	[28]
RCT / Obese hypertensive patients	3 weeks	Probiotic cheese *L. plantarum* TENSIA + low-calorie diet	3 weeks	Single-strain	Reduced BMI and morning diastolic BP associated with colonization	[29]
Animal / SHR rats	-	*L. fermentum* CECT5716 + *L. coryniformis* K8 + *L. gasseri* LC9	Variable	Variable	Reduced SBP, cardiac and renal hypertrophy, improved endothelial function and NO	[30]
RCT / Women, Hypertensive	8 weeks	*Lactobacillus* and *Bifidobacterium*	8 weeks	Multi-strain	BP reduction observed but not statistically significant; improved cardiac autonomic metabolism (LF/HF)	[31]
Animal / Preeclampsia rats	-	Probiotics	Variable	Variable	Reduced serum endotoxin and hs-CRP, increased NO, decreased ET-1, improved BP and endothelial function	[32]
Animal / SHR rats	-	Probiotic cheese *Minas Frescal*	Variable	Variable	Reduced BP, improved triglycerides and cholesterol	[33]
Animal / DOCA-salt hypertension	-	*B. breve* CECT7263 (BFM)	Variable	Variable	Prevented BP elevation, improved heart and kidney function, restored gut flora, balanced Th17/Treg	[34]
Animal / SHR rats + L-NAME	-	*L. fermentum* CECT5716 (LC40)	Variable	Variable	Prevented dysbiosis, improved Th17/Treg balance, reduced oxidative stress and inflammation; antihypertensive effect NO-dependent	[35]
Animal / SHR rats	-	Kefir	60 days	Variable	15% reduction in BP and tachycardia, reduced ROS, increased NO, improved endothelial function	[36]

Systematic review / Prediabetes	60	Probiotic capsule 500 mg	8 weeks	Variable	Reduced SBP; no significant change in lipid profile	[37]
Systematic review / Adults	2,102	Fermented milk with probiotics (PFM)	Variable	Variable	Reduced SBP and DBP in prehypertensive/hypertensive individuals; effects dependent on duration, BMI, and age	[38]
Animal / SHR rats	-	*Clostridium butyricum*-pMTL007-GLP-1	Variable	Variable	Significant BP reduction, improved cardiac parameters, activated AMPK/mTOR pathway, restored gut microbiota	[39]
Animal / SHR rats	-	Kefir	70 days	Variable	Reduced BP and tachycardia, improved endothelial function, partial progenitor cell restoration	[40]

Discussion

Hypertension, as one of the most important modifiable risk factors for cardiovascular disease, remains highly prevalent despite advances in pharmacotherapy. Its management is often challenged by poor treatment adherence and the side effects associated with conventional medications [41]. Consequently, there is a growing need for safe and sustainable complementary approaches. Recent advances in understanding the role of gut microbiota in blood pressure regulation have brought probiotics into focus. Increasing evidence from both animal and human studies suggests that probiotics may help lower blood pressure through modulation of gut dysbiosis, enhanced production of short-chain fatty acids (SCFAs), reduction of systemic inflammation and oxidative stress, and improvement of endothelial function and nitric oxide bioavailability [42]. The development of targeted formulations, identification of strain-specific antihypertensive probiotics, and the movement toward personalized medicine underscore the progress in this field and highlight the potential of probiotic therapy as a novel adjunctive strategy for hypertension management [43].

Findings summarized in Table 1 indicate that probiotic therapy and the consumption of fermented products are generally associated with modest but reproducible reductions in both systolic and diastolic blood pressure. This trend has been consistently reported in meta-analyses and umbrella reviews, particularly in populations with hypertension, prehypertension, and type 2 diabetes [19–23, 26, 28]. Although the effect size in most human studies is moderate from a clinical perspective, even a 2–5 mmHg reduction in systolic blood pressure at the population level can translate into a meaningful decrease in cardiovascular events, emphasizing its clinical relevance.

Comparative analysis of human studies highlights that heterogeneity in intervention type, dose, duration, and population characteristics plays a pivotal role in determining the magnitude of blood pressure-lowering responses. Stronger evidence supports interventions lasting at least eight weeks, higher doses ($\geq 10^{10}$–10^{11} CFU), and multi-strain formulations or fermented dairy products [20, 23, 28, 38], whereas shorter interventions or single-strain probiotics often demonstrate weaker or non-significant effects [22, 31]. Nevertheless, some meta-analyses have not observed clear differences between single- and multi-strain probiotics [19], suggesting that host factors including metabolic status, age, BMI, and baseline blood pressure may exert a dominant influence.

At the mechanistic level, there is notable convergence between human and animal data. Animal studies consistently demonstrate that probiotics prevent or attenuate hypertension through modulation of gut dysbiosis, increased SCFA production, improved Th17/Treg immune balance, reductions in endotoxemia, systemic inflammation, and oxidative stress, and enhanced nitric oxide bioavailability [24, 27, 30, 34–36, 39, 40]. These findings provide a strong biological rationale for the effects observed in human studies and indicate that the gut–vascular axis represents a promising therapeutic target.

Another important consideration is the influence of the fermented product type. Studies utilizing fermented milk, yogurt, or kefir often report more pronounced and sustained effects on blood pressure and endothelial function [21, 27, 33, 36, 38, 40], likely due to the combined effects of probiotics with bioactive metabolites and the food matrix. This underscores that both formulation and strain selection are critical determinants of clinical outcomes. Diabetes is one of the most significant chronic metabolic disorders which, due to its high prevalence and serious complications such as cardiovascular diseases, renal failure, and neurological disorders, imposes a substantial burden on global healthcare systems [44-46]. Novel therapeutic approaches such as probiotics play a significant role in the improvement and management of diabetic wounds by modulating the microbiota, reducing inflammation, and accelerating tissue repair. Overall, the integrated analysis of human and animal studies suggests that probiotic therapy may serve as a safe, mechanism-based adjunct in hypertension management. However, substantial heterogeneity in study outcomes, the short-term nature of many interventions, and the lack of long-term data highlight the need for large-scale, rigorously designed clinical trials. Future research should incorporate personalized approaches that tailor strain selection, dose, and intervention duration to individual patient characteristics, optimizing the therapeutic potential of probiotics in blood pressure regulation.

Conclusion

Probiotic therapy may serve as an effective adjunctive strategy for lowering both systolic and diastolic blood pressure, particularly in individuals with hypertension, prediabetes, and type 2 diabetes. These effects are primarily mediated through modulation of the gut microbiota, increased production of short-chain fatty acids, attenuation of systemic inflammation and oxidative stress, and improvement of endothelial function. Multi-strain formulations and fermented dairy products administered for at least eight weeks appear to confer the most pronounced benefits. However, the observed effects are generally moderate and short-term, with treatment responses influenced by individual characteristics and dosage. Therefore, well-designed, long-term clinical trials with a personalized medicine approach tailoring strain selection, dose, and duration to individual patient profiles are warranted to establish the efficacy and sustainability of probiotic therapy in blood pressure management.

Statements and Declarations

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Competing interests

The authors have no competing interests to declare that are relevant to the content of this article.

Ethics approval

This study was performed in line with the principles of the Declaration of Helsinki.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Author contributions

EM: Conceptualization, the original draft writing, investigation, writing including reviewing and editing and investigation and formal analysis; EM: Conceptualization, supervision, and project administration; EM Conceptualization, the original draft writing, investigation, writing including reviewing and editing.Acknowledgments

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